

## POLYPROPYLENE

# New array of polymer variations expand end-use applications

Few materials are as compatible with as many processing techniques or are used in as many commercial applications as polypropylene. It is found in everything from flexible and rigid packaging to fibers

sheet, fiber, and filaments. Another 2.2 billion lb. went into injection molded parts for appliances, consumer products, medical equipment, rigid packaging, transportation, and other uses. More than 1 billion lb. of

motive applications its used in.

Polypropylene is produced when propylene monomer is polymerized under controlled conditions of heat and pressure in the presence of Ziegler Natta catalysts. There are three basic types of polypropylene: isotactic, atactic, and syndiotactic. Each variety has a well-defined niche in the industrial sector.

Isotactic polypropylene, which contains ordered monomer units inserted in the same configuration, is the most common commercial polypropylene. Its molecular structure allows it to assume a helical and crystalline configuration, which makes the material stiff enough for use in a wide range of commercial applications.

Isotactic polypropylene has a density of 0.90-0.91 g./cc., and a melting point of 165°C. The melt-flow rate for this material ranges from under 0.3 g./10 min. for extruded sheets to greater than 800 g./10 min. for some fiber grades. It also has a notched Izod impact range at 23°C. of between 0.4 and 3.5 ft.-lb./in. for the same applications.

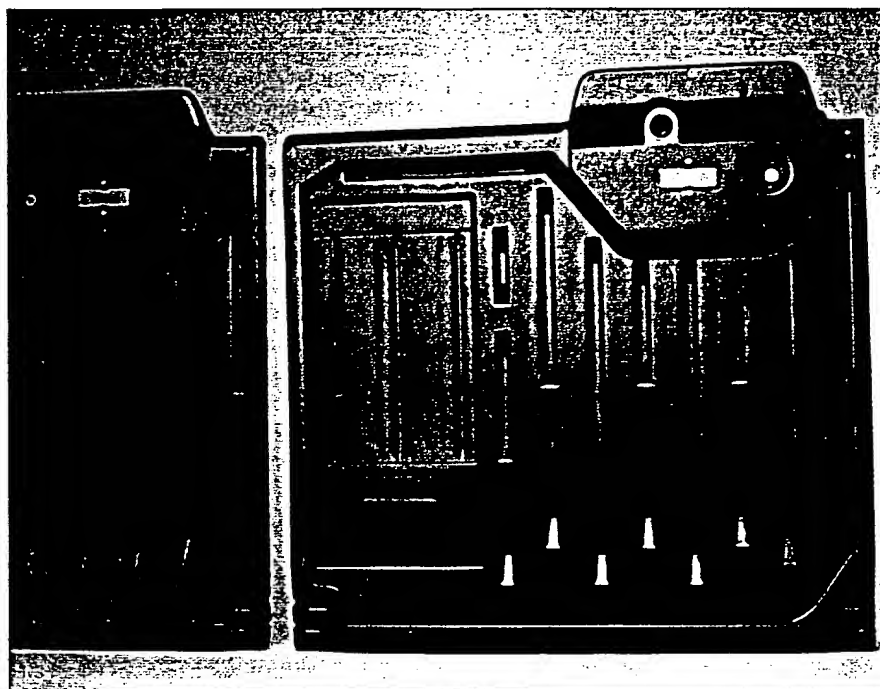
### Fillers boost stiffness and strength of resin

One of the common ways to modify isotactic polypropylene is to add a filler, such as calcium carbonate or talc, in concentrations of 20-40%, to increase the stiffness of the material. Glass filler is sometimes used to increase the tensile strength and flexural modulus above the levels possible with standard fillers.

Increased stiffness and tensile strength in isotactic polypropylene can also be achieved by nucleation or by broadening its molecular-weight distribution and increasing its stereoregularity (isotacticity). The resulting resins are referred to as "high-crystallinity" polypropylenes.

Atactic polypropylene, which has a random molecular pattern, lacks the crystalline structure needed in most

*Amorphous*



Automotive seat-back substrates are among large blow molded parts made from very-low-melt-flow, high-melt-strength polypropylene. Automotive is a major polypropylene market. [Photo, Himont]

and large molded parts for automotive and consumer products. The material can be processed by most methods, including extrusion, extrusion coating, blown and cast film, blow molding, injection molding, and thermoforming.

In 1992, more than 8.5 billion lb. of polypropylene were produced in the U.S. and 31 billion lb. were produced worldwide. More than 3 billion lb. of the U.S. output were used for extruded products, such as film,

the remaining output were exported to other regions of the world.

The high production figures and diversity of applications reflect the many advantages of polypropylene. These include resistance to most organic solvents, with the exception of very strong oxidizing agents such as fuming nitric acid or sulfuric acid. Polypropylene also has the lowest specific gravity of any volume thermoplastic and offers a wide variety of melt flow rates (from 0.3 to 800 g./10 min.). Other advantages of the resin include its high melting temperature (approximately 165°C. for homopolymer), and its ease of recycling, an important consideration in many of the packaging and auto-

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commercial applications. It is commonly used as an adhesive, or mixed with other materials, such as asphalt, for roofing applications.

Syndiotactic polypropylene, which is not yet commercially available, offers lower melting points, better impact resistance and more clarity than isotactic homopolymer polypropylene. The syndiotactic polymer contains monomer units inserted in an alternating configuration but has a regular molecular structure.

### Fibers are the leading homopolymer application

Commercial isotactic polypropylene is available in the form of homopolymers, copolymers, and random copolymers. Homopolymer polypropylene grades are produced from propylene monomer without other monomers. Their main applications are in fibers and filaments, oriented and cast film, injection molded parts and blow-molded bottles.

Fibers and filaments, the largest use of the homopolymer, consumed some 2 billion lb. of polypropylene in the U.S. in 1992. Markets for homopolymer resin include: continuous, bulked-continuous, and staple multifilament fibers for textiles and carpeting; monofilaments such as slit tape for carpet backing and bags; decorative ribbons; netting and strapping as well as spun-bonded and melt-blown nonwovens.

Melt-blown fiber producers have employed homopolymer grades with a melt-flow rate as high as 800 g./10 min. These applications require finer-denier fibers with high tensile strength, and reduced processing temperatures and die pressures.

In oriented and cast film, homopolymers provide clarity and gloss, high tensile and tear strength, stiffness, and a wide heat-sealing range. Other features of homopolymers include good moisture-barrier properties and printability.

Cast film is used in food packaging, bags for textiles, and (in combination with other materials) for composite packaging film laminates. Oriented polypropylene film achieves its high strength, clarity, and impact resistance due to mechanical processing (orientation) that aligns the polypropylene molecules.

It is often used in food packaging, particularly for snacks; cigarette packaging and pressure-sensitive tapes are other applications.

Polypropylene is widely employed to fabricate injection molded items. One reason is that the polymer can form an injection molded "living hinge" — one that can repeatedly open and close — which is often used in closures or containers. Polypropylene also has low odor and taste transfer for items in contact with it. Other injection molded applications include consumer products such as file boxes and video cassette cases; medical equipment such as disposable pipette tips, syringes, and vials that resist radiation sterilization; and various housewares such as containers, bins, and bowls.

In blow molded bottles, the homopolymers provide good clarity, precise wall-thickness control, and a high neck finish. The slip properties of the homopolymers also allow bottles to be easily released from molds.

Polypropylene copolymers find a wide range of applications. In particular, heterophasic copolymers are used in large automotive parts which must withstand high temperatures without distortion. Heterophasic

copolymers are formed when a rubber phase, usually ethylene-propylene rubber, is polymerized with the homopolymer phase during manufacture. The addition of rubber increases the impact resistance of the material, especially at low (sub-freezing) temperatures, while the homopolymer provides stiffness. These materials are also available as blush-resistant copolymers, where a polyethylene component helps prevent the stress-whitening associated with impact.

Typically, the melt-flow rates of heterophasic copolymers range from 0.4 g./10 min. for extruded sheet grades to 70 g./10 min. for injection molding grades. The density is about 0.90 g./cc., and the notched Izod impact at 23°C. ranges from 1.0 to more than 10 ft.-lb./in. for the same applications.

The primary applications for heterophasic copolymers include injection molded parts, thermoformed containers, and blow molded parts. Injection molded consumer products such as child safety seats, luggage and tackle boxes, appliance and automotive components, take advantage of the high-impact strength of the heterophasic materials. (Polypropylene is easily stabilized against ultra-

violet degradation for use in outdoor applications.)

Melt-phase thermoformed items such as microwavable food packaging are another outlet for the heterophasic copolymers. Fabricating such products requires the use of high-speed web equipment. The copolymer offers not only the deep draw and wide web necessary in such processing, but also the low odor and taste transmission needed in the final products. Other copolymer grades are compatible with solid-phase pressure forming.

Some heterophasic copolymers are used



High-melt-flow-rate polypropylene is injection molded into containers weighing 15-30% less than polyethylene counterparts. [Photo, Himont]

## Overcapacity keeps polypropylene prices in check

Polypropylene has been characterized for several years by overcapacity and, consequently, low prices. The modest prices are allowing polypropylene to make inroads at the expense of other materials, a process aided by new technologies that extend polypropylene properties.

Excess polypropylene capacity stems from the global expansion surge in 1988 through 1991, when capacity more than doubled in Europe and increased 36% in North America. In South Korea alone, polypropylene capacity rose by 1 billion lb. from 1991 to 1993. New monomer capacity is likely to dampen pressure on propylene costs worldwide.

Pricing, consequently, is at its lowest in years. Neste Chemicals, Espoo Finland, notes that European polypropylene prices hit unprecedented lows in September, 1992. In December, raffia-grade resin traded in Belgium for 19¢/lb. In the U.S., molding-grade homopolymer hit 31¢/lb. in the fourth quarter of 1992, down 20% from its high earlier in the year.

A more balanced market is likely to emerge by late 1993-94 in the U.S. Suppliers are well along in eliminating old, costly slurry capacity. And in Europe, suppliers seek to rationalize. In addition to soft economies there, they are saddled with inefficient capacity (some 24% of nameplate is slurry) and have limited access to monomer pipelines. Meanwhile, technologies that impart above-average heat deflection temperature, stiffness, hardness, clarity, gloss, and barrier to grades are emerging.

High-crystallinity polypropylene, for example, is targeting such materials as ABS in automobile interiors, and polystyrene and PVC in packaging. High-modulus grades of polypropylene, as produced via Himont's Catalloy polymerization technology, are expected to challenge clear plastics (such as PET) and glass in container applications. Other companies that have launched enhanced polypropylene lines include Hoechst, Amoco, and Solvay.

According to industry sources, extrusion blow molded polypropylene grades are making gains as low-cost options to polystyrene. Facilitating this trend is the growth of vacuum-deposition glass-coating technologies, which improve the barrier properties of polypropylene films and containers. [Modern Plastics]

for large or heavy-parison blow molded parts due to the excellent parison stability they provide. In addition, they provide uniform wall and corner foundations.

### Random copolymers replace glass food containers

Random copolymers, another important variety of polypropylene, are noted for high clarity, a lower, broader melting range than homopolymer grades, and reduced flexural modulus. They are produced by the random addition of ethylene to a polypropylene chain as it grows. At refrigerator temperatures, these materials also have impact resistance which is greater than that of homopolymers, but less than heterophasic copolymers. Orienting the material further improves its clarity and impact resistance.

The melt-flow rate of random copolymers ranges from 1 g./10 min. for a blow molding grade to 30 g./10 min. for an injection molding grade. The density is about 0.90 g./cc., and the notched Izod impact strength of the materials ranges from under 1 to more than 5 ft.-lb./in.

The applications and markets for random copolymers include injection molded housewares, blow molded

bottles, and cast film. The injection molded products, such as food storage containers, take advantage of the excellent clarity and good balance of impact and stiffness of this material. The blow molded bottles capitalize on the good clarity provided by the random copolymer. And the high-temperature resistance, high gloss, and very broad heat-sealing range of this resin is useful in such cast-film applications as trading cards and document protectors.

### High-flow grades permit thinwalling of containers

From the three basic categories of polypropylene, there are specialty resins with enhanced capabilities for specific applications.

Polypropylene copolymers with a melt flow rate of 35 g./10 min. or above find applications in thinwall parts, usually for injection molded food packaging such as delicatessen containers or yogurt cups. Such containers have walls with a length-to-thickness ratio as high as 400:1, yet they retain the properties of top-load strength, impact resistance, and recyclability that are typical of polypropylene. In other cases, injection molders have used these specialized copolymers to reduce container

weights by 30% over containers produced with other materials.

Meanwhile, extrusion coaters can now make use of high-melt-strength polypropylene resins with melt-flow rates as high as 40 g./10 min. These materials resist pinholes and curling, while providing very low neck-in. Their high melt-flow rates also permit an increase in processing line speeds, which leads to improved productivity and economy.

Producers of large blow molded or thermoformed parts can utilize grades with improved melt strength. In applications such as automotive parts, household appliances, industrial food trays, and water-storage tanks, the resins provide resistance to chemicals, thermal shock, and heat distortion up to 210°F. at 66 p.s.i. Future applications envisioned for the high-melt-strength resins will include heat-resistant "under-the-hood" automotive parts.

The full potential of the many varieties of polypropylene has hardly been tapped. The resin now seems poised for further penetration of markets ranging from automotive to medical packaging, as designers and specifiers awaken to the wide slate of processing and performance possible with the material. □